Searching for Quasi-Dyson Spheres

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1 Abstract

A neighboring star orbited by very large numbers of space colonies hosting water based life may exhibit spectral signatures distiguishable from dust and debris. These signatures depend only on thermodyamics and may be detectable by current or soon-to-be operational instruments, making the existence of very large civilization of orbital space colonies around nearby stars a testable hypothesis. We describe the beginings of a search of online astronomical databases to detect such civilizations.

2 Introduction

Assume

1. there is no technological short-cut to the laws of thermodynamics, as we know them
2. our civilization continues to expand for perhaps a million years, a small fraction of the lifetime of a star
3. we start building orbital space colonies in the next thousand years or so

In this case, we might be observable to a civilization orbiting a nearby star possessing instruments similar to what we have today. Turning this around, if civilizations similar to ours a million years hence are common in our stellar neighborhood, we may be able to observe them with current or soon-to-be deployed instruments. Specifically, a star orbited by very large numbers of space colonies may have excess emissions in the infrared or even be dimmed. Such a star may be described as a Quasi-Dyson Sphere (QDS). Freeman Dyson

[Dyson 1960] proposed artificial structures completely enclosing a star, but such structures are gravitationally unstable [reference]. However, sufficiently large numbers of orbital colonies around a star would partially block and convert a star's energy. If n% of a star's energy is blocked, we may say that this star is a n% QDS. Given instruments that can detect an n% QDS, the existence of such civilizations, at least in our stellar neighborhood, becomes a testable, falsafiable hypothesis.

The search for extraterrestrial intelligence (SETI) has been dominated by the attempt to detect radio signals [reference] on the questionable assumption that other civilizations will attempt deliberate communications and/or that their communication systems are inefficient. While it is true that our present radio frequency communication systems are inefficient in the sense that much of the signal does not reach the intended recipients but is rather broadcast into space, this inefficiency is a function of our current technology and is unlikely to last more than a few centuries or millenia. As a fraction of the multi-billion year life of a star, this is an insignificant length of time. Thus, even if we point our radio telescopes in the right direction, we are unlikely to happen to be at the right time. By contrast, the signatures this paper proposes for detecting QDS should last millions or even billions of years, although only a restricted set of potential civilizations will emit these signals.

3 Infrared Excess

One approach to detecting a QDS is to look for the infrared emissions produced by artificial thermal radiators. Assuming there is no work-around to our laws of thermodynamics, colonies must absorb a star's energy (or produce new energy), use it and reject the heat to deep space. The heat must be rejected at temperatures below utilization temperatures. The higher the temperature the more efficient the heat rejection. For water based life, therefore, the temperature of the heat rejection systems can be assumed to be in the range 273-373K (the temperature of liquid water). Thus, a QDS star's energy output curve should be somewhat different than a purely natural solar system, with a small artificial peak in the 10-20 micron range. The hight of the peak is related the completeness of the QDS. Once a star with such an infrared excess is found, it is necessary to distinguish between the infrared excess of space colonies and naturally occurring dust or debris. There are two approaches to this discrimination: the temperature range of the source and the age of the star. The temperature of the dust is determined by the distance from the star and the size and composition of the dust. From these parameters the expected spectrum can be calculated. Since any given thermal technology should have an optimal temperature, artificial emissions should be closer to black body radiation. Thus, high spectral resolution data between 10-20 microns, as is available from the Keck infrared instrument [reference], may be able to distinguish between natural debris and large numbers of space colonies. Second, dust is usually associated with younger stars. If our star develops a QDS it will have taken at least 5 billion years. Thus, a reliable means for determining the age of stars would help distinguish QDS from dust. The literature contains at least two attempts to find an infrared excess associated with a QDS.

1. Jugaku, Noguchi, and Nishimura have searched 53 nearby stars with a 1.26 m infrared telescope in Japan and examined IRAS (http://space.gsfc.nasa.gov/astro/iras/iras_home.html) data for 135 more looking for a 10-20 micron infrared excess [Jugaku, Noguchi, and Nishimura 1995]. They claim that the sensitivity of the instruments should be sufficient to detect a 1% QDS. No candidates have yet been found.

2. Slysh [Slysh 1985] examined the IRAS data for 100% DS candidates, specifically 0507+528 P05, 0453+444 P03, 0536+467 P05, and 0259+601 P02 without finding a candidates, however noted that G 357 .3-1.3 [Gautier et al. 1984] is strong source with a 220K blackbody spectrum and claims this is a good 100% QDS candidate, however the temperature is suspiciously low. Slysh notes that it is difficult to distinguish a 100% QDS from circumstellar dust shells around an evolved red giant.

As new instruments become available a search of greater sensitivity becomes possible. For example, the SIRFT (Space Infrared Telescope Facility, see http://sirtf.caltech.edu/) is expected to launch soon. We may examine the capabilities of this instrument for QDS detection by assuming a cloud of individual space colonies orbiting in a belt where equilibrium T = 300 K. Assuming the colonies would not be confined to the same orbital plane because that limits the number of colonies and also makes them shadow each other. If the are distributed about an ecliptic mid-plane the only way to do that is to have them in orbits inclined to the ecliptic, i.e. each individual colony will oscillate vertically about the mid-plane as it orbits the star. This oscillation should not have a large amplitude otherwise the colonies would have large velocities relative to each other and it would be difficult to move personnel and supplies between colonies. Traffic control problems also suggest small colony-colony relative velocity dispersion is desirable.

Assuming the torus/belt of colonies has a vertical extent of order 1/1000 of their stellar orbit radius, i.e. 150,000 km at 1 AU. That makes cross-velocities between colonies of order $V_{orb}/1000 \approx 30 meters/sec$. Further, assume the torus is filled with colonies to the point that the "optical depth" for a ray from the star to infinity would be no more than 0.1, i.e. viewed from a given colony at most 10 percent of the sun is blockd by other colonies.

Following from these assumptions about 'vertical' extent of the colony swarm and upper limit on mutual shadowing, the total cross-sectional area of all the colonies around a solar-type star would be: $2\pi \times 10^{-4} AU^2$, or $1.4 \times 10^{19} m^2$, which is 10^5 times the land area of Earth. The total bolometric luminosity of stellar radiation intercepted by the colonies and re-radiated in the IR would be $5 \times 10^{-5} L_{sun}$.

The contrast to the star at specific wavelengths are found in table 1.

wavelength (microns)	total F_{nu} from colonies relative to G2 photosphere (%)
15	7
24	16
70	33

Table 1: ????

To detect the IR excess from the colonies with 5-sigma precision and do it in 500 sec integration time, the pre-launch sensitivities for SIRTF imply the stellar photosphere must be brighter than 2.3 mJy at 24 microns. For a solar-type star this means distance less than 120 pc. 24 microns appears to be the best compromise between rising relative flux from the 300 K colonies vs. decreasing relative sensitivity of SIRTF.

4 Temperature/Luminosity Anomaly

Another approach to finding an n% QDS, albeit with high n, is to search for main sequence stars with low luminosity relative to other main sequence stars of the same temperature. A main sequence star's mass determines it's temperature [reference] and therefor it's absolute magnitude. If the distance to a star is accurately know, it's absolute luminosity can be calculated from it's apparent brightness. The European Hipparchos satellite (http://archive.ast.cam.ac.uk/hipp/) calculated very accurate distance to nearby stars using parallax. We have extracted 299 stars from the Hipparchos catalogue that exhibit low luminosity relative to other stars with similar temperatures. The stars were selected to have:

$$
\begin{aligned}
p &\geq 20 && (1)\\
T_c &= \frac{7300}{B-V+0.73} && (2)\\
T_c &\leq 8000 && (3)\\
M_h &\leq 27.31 - 0.002149T_c && (4)\\
M_h &\geq 17.805 - 0.001681T_c && (5)
\end{aligned}
$$

where p is the Hipparchos parallax, $B-V$ is from the Hipparchos catalogue, and M_h is the Hipparchos (absolute) magnitude based on apparent magnitude and the Hipparchos distance. T_c is the temperature as calculated from $B-V$. Fred – need explanation of $B-V$.

5 Conclusion

With the advent of internet accessible archives of astronomical data, such as the Hipparchos catalogue and the IRAS database [reference], it is possible to design

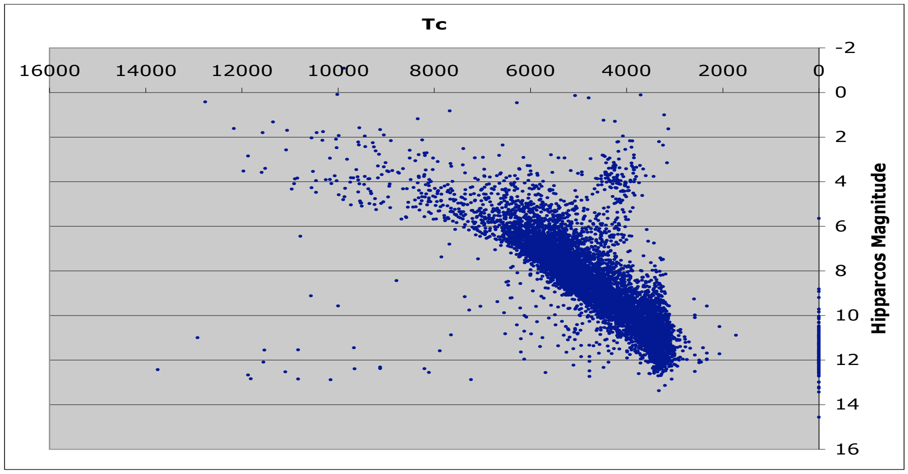

Figure 1: All of the stars from the Hipparchos catalogue that satisfy eq. 1.

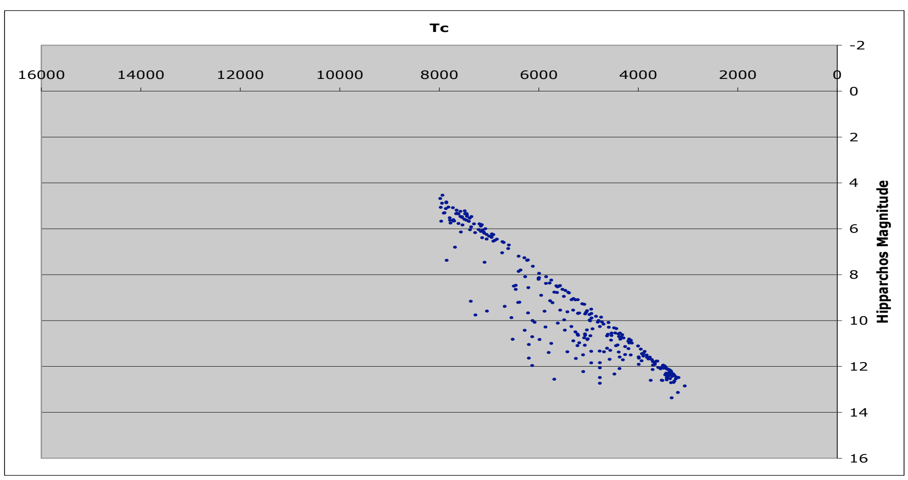

Figure 2: All of the stars from the Hipparchos catalogue that satisfy eq. 1-5. These are candidates for further evaluation.

computer searches for candidate QDSs. With new, more powerful infrared instruments becoming available, such as SIRTF [reference], pledged to put their data on the net, new opportunities for inexpensive, computerized search for QDS will become available. Combined with a search for passive signatures of large scale orbital civilizations, we now have a testable hypothesis that can lead the quantification of an upper limit to the density and size of QDS in our stellar neighborhood.

6 Acknowledgements

7 References

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